UNIVERSITI PUTRA MALAYSIA

SEED FORMATION AND DEVELOPMENT IN COCOA (THEOBROMA CACAO L.)

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SEED FORMATION AND DEVELOPMENT IN COCOA

(*Theobroma cacao* L.)

by

T. Chairun Nisa Haris

A thesis submitted in partial fulfilment of the requirements for the degree of Master of Agricultural Science in the Faculty of Agriculture, Universiti Pertanian Malaysia

May 1988

A C K N O W L E D G E M E N T S

The author is greatly indebted to her supervisors, Associate Professor Dr. Mohammad B. Mohd. Lassim (from December 1985 until December 1987) and Dr Hor Yue Luan of the Department of Agronomy and Horticulture, Universiti Pertanian Malaysia, for the invaluable supervision, guidance, advice, constructive criticisms and suggestions given throughout the course of this study.

Deep appreciation is also due to the Department of Agronomy and Horticulture UPM, for making available all the materials needed in the study.

Special thanks are given to Mr. How Peng Guan of the Department of Agronomy and Horticulture, for his invaluable help in preparing the permanent mount slides of the cocoa specimens, Mr. Abdul Gani of the Department of Biology, Faculty of Science and Environmental Studies, for his help in photogaphy, and to all the staff of the Seed Technology Laboratory of the Department of Agronomy and Horticulture, for their assistance during the course of the study.

To her husband, Ir. H. Tengku Haris Aminullah and her family, the author conveys her special thanks and appreciation for their support, understanding, encouragement and countless sacrifices.

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SEED FORMATION AND DEVELOPMENT IN COCOA (THEOBROMA CACAO L.)

by

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May 1988

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Faculty : Agriculture

A study on cocoa (Theobroma cacao L.) seed formation and development was undertaken at the Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia. The plant materials used comprised of five dissimilar crossings of Sabah Mixed Hybrid. Freshly opened flowers were hand-pollinated and tagged to ascertain the date of pollination. The tagged flowers were then covered with plastic-net bags to protect them from insects and other hazards. Samples were taken at weekly intervals. Changes in the histology and germinability of seed, as well as size, weight and moisture content of both fruit and seed were determined. In addition, the effects of air drying on seed germinability was also studied.

Progressive development of the endosperm and embryo started to occur eight weeks after pollination and it continued to do so until complete development was attained 11 weeks later (19th week). Physical development of the fruit and seed followed a three-phase sigmoidal pattern. The first phase was characterised by very slow growth rate of both the fruit and seed during the first eight weeks after pollination. This was followed by a period of rapid increases in dimensions and weights until maximum values were reached 18 weeks after pollination. The final developmental phase (beyond the 18th week) was a period of minimal physical changes. Maximum seed dry weight was attained 22 weeks after pollination at which seeds are regarded as physiologically mature. Seed moisture content was high (above 90 percent) during the initial stages of development. It then declined steadily reaching a fairly stable value of about 40 percent approximately 25 weeks after pollination. Fruit moisture content on the other hand, remained relatively high (above 70 percent) throughout the developmental period.

The characteristics of fruits obtained from the mixed hybrid crossings used in the present study showed high variability. The number of seeds per pod was a characteristic of the material and was not influenced by age.

Seed germination tests showed that seeds were capable of germinating as early as the 15th week after pollination (seven weeks earlier than the attainment of physiological maturity) High germination values were recorded for seeds which were 17 weeks or older. Air drying for 24 hours adversely affected the germinability of young, immature seeds. Seeds older than 17 weeks were observed to be able to withstand the 24-hour air drying treatment. However, 48 hours of air drying proved to be detrimental to the germinability of cocoa seeds of all ages.

Abstrak tesis yang dikemukakan kepada Senat Universiti Pertanian Malaysia sebagai memenuhi sebahagian daripada syarat-syarat keperluan untuk Ijazah Master Sains Pertanian.

PEMBENTUKAN DAN PERKEMBANGAN BIJI BENIH PADA TANAMAN KOKO (THEOBROMA CACAO L.)

oleh

T. CHAIRUN NISA HARIS

May 1988

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Fakulti : Pertanian

Satu kajian terhadap pembentukan dan perkembangan biji benih koko (Theobroma cacao L.) telah dijalankan di Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia. Bahan tanaman yang digunakan terdiri dari lima kacukan Hibrida Campuran dari Sabah yang berlainan. Pendebungaan berbantu dilakukan keatas bunga segar yang baru terbuka dan tiap-tiap satu ditanda untuk menentukan tarikh pendebungaan. Bunga-bunga berkenaan ditutup dengan beg jaringan plastik untuk mengelakkan dari serangan serangga dan kerosakan lain. Sampel diambil setiap minggu. Perubahan-perubahan histologi dan percambahan biji benih serta saiz, berat serta isi kandungan

air buah dan biji benih ditentukan. Kesan pengeringan udara terhadap percambahan biji benih juga telah dikaji.

Endosperma dan embrio diperhatikan mula berkembang secara progresif pada minggu ke lapan selepas pendebungaan dan proses ini terus berlaku sehingga selesai perkembangannya 11 minggu kemudian (minggu ke 19). Perkembangan fizikal buah dan biji benih berlaku mengikut pola sigmoid tiga peringkat. Peringkat pertama, dalam masa lapan minggu pertama, merupakan satu jangkamasa dimana kadar pertumbuhan buah dan biji benih adalah sangat rendah. Peringkat ini disusuli oleh satu jangkamasa dimana pertambahan saiz dan berat berlaku dengan cepat sehingga tercapainya nilai maksima 18 minggu selepas pendebungaan. Peringkat terakhir dalam proses perkembangan (selepas minggu ke 18) merupakan satu jangkamasa dimana perubahan fizikal adalah minima. Nilai berat kering maksima biji benih tercapai 22 minggu selepas pendebungaan dan pada saat itu biji benih dianggap telah mencapai kematangan fisiologi. Isi kandungan air biji benih adalah tinggi (melebihi 90 peratus) pada peringkat awal perkembangan. Ia kemudiannya menurun sehingga mencapai satu tahap yang stabil sekitar 40 peratus, kira-kira 25 minggu selepas pendebungaan. Sebaliknya, isi kandungan air buah tetap tinggi secara relatif (melebihi 70 peratus) sepanjang jangkamasa perkembangan.

Sifat-sifat buah yang dihasilkan oleh tiap-tiap kacukan hibrida bercampur yang digunakan dalam kajian ini mempunyai banyak perbezaan. Bilangan biji benih per buah merupakan sifat bahan tanaman dan tidak dipengaruhi oleh umur biji benih.

Ujian percambahan biji benih menunjukkan bahawa biji benih berkemampuan untuk bercambah pada minggu ke 15 (7 minggu lebih awal dari masa tercapainya kematangan fisiologi). Biji benih berumur 17 minggu atau lebih menunjukkan nilai percambahan yang tinggi. Pengeringan udara selama 24 jam mempunyai kesan buruk keatas percambahan biji benih muda dan belum matang. Biji benih berumur 17 minggu atau lebih, menunjukkan ketahanan terhadap perlakuan pengeringan udara selama 24 jam itu. Walau bagaimanapun, pengeringan udara selama 48 jam mempunyai kesan buruk terhadap semua biji benih koko tanpa mengira umur.

CHAPTER I

I N T R O D U C T I O N

Cocoa (Theobroma cacao L) represents one of 22 species which belong to the family Sterculiaceae, a family of the order Malvales. It is an important tropical crop, providing seeds or "beans" which are widely used in the manufacture of eating chocolate, drinking cocoas and cocoa butter, and to a lesser extent, in the manufacture of cosmetics and pharmaceutical preparations (Urquehart, 1961; Wigall, 1969; Vaughan, 1970). The plant is thought to originate from Central and South America, where it grew wild in the tropical rainforests, until it became cultivated since the 16th century. During the 17th and 18th centuries the cocoa plant was introduced to many countries, including West Africa (Urquehart, 1961; Wood, 1975).

Although cocoas and chocolate are consumed primarily for pleasure rather than for their nutritional value, nevertheless they have an important role to play as a supplement to a balanced diet. They contain a proportion of the main classes of nutrients, i.e. carbohydrates, fats and proteins, and also certain vitamins (Wigall, 1969; Vaughan, 1970). The consumption of chocolate has increased from year to year, and

varies among countries. Nowadays the main consumption is centred in the United States and West Europe (Anonymous,1986). Of the two cocoa types produced, fine cocoa from Criollo beans and bulk cocoa from West African and Brazilian beans, the bulk consumption for cocoa and chocolate industries nowadays is on bulk cocoa, while fine cocoa is only used as blending material (Anonymous, 1985; Soenaryo and Siswanto, 1985). The increasing demand for cocoa resulted in large expansions in the cultivation of the crop. In Malaysia, its expansion has become one of the government's policies for agricultural development (Ibrahim, 1986).

Propagation of the cocoa plant is largely sexual, although asexual propagation (mainly through budding), is also done. But even for the purpose of budding, good seeds are needed to provide stock seedlings. Therefore the demand for seeds as planting material remains relatively high due to more areas being designated for new planting as well as replanting schemes.

Seeds to be germinated are usually taken from ripe mature pods, which have turned yellow. This colour development is used as an index of maturity based on the assumption that only beans extracted from these pods can give good germination and adequately vigorous seedlings (Adenikinju, 1971). Such pods are, however, subject to hazards of black pod disease caused by Phytophthora palmivora Butl, or other hazards before they

are harvested, usually 24 to 25 weeks after pollination. Occurence of black pod disease is usually high during the wet season, reducing fruit yield as high as 50 percent (Pereira, 1985; Wardoyo and Soekirman, 1985). Since peak production in Malaysia is obtained from October to December, which coincides with the wet season, care need to be taken to prevent the fruits from being attacked by the disease.

One alternative is to harvest fruits before full maturity or ripeness, whenever this does not affect germination. Previous studies on germination of other crops' seeds showed that the maximum germination percentage could occur before physiological maturity. But maximum vigour is attained at physiological maturity, which coincides with maximum seed dry weight. Thereafter seeds begin to age and deterioration sets in (Abdul-Baki and Anderson, 1972; Anderson, 1973; Thomson, 1979). Therefore, seeds should be harvested at or immediately after the attainment of physiological maturity.

In order to ascertain when physiological maturity is attained, studies on seed development should be done. Several published reports on seed development of legumes, grains, and other orthodox seeds are available. Published work on recalcitrant seeds such as cocoa is lacking. The few studies on development of cocoa seeds included those done by Cheeseman (1927), Nichols (1965a), Roth and Lindorf (1971) and

Adenikinju (1975), for cocoa in Africa and Venezuela. No studies on seed formation and development under Malaysian conditions have been carried out. Therefore the objectives of this research are as follows:

a. To study the formation and development of cocoa seeds.
b. To study the viability/germinability of cocoa seeds at the different stages of development.
c. To observe the effect of air drying on germinability of cocoa seeds at different stages of development.

CHAPTER II

L I T E R A T U R E R E V I E W

Flowering and Seed Setting in Cocoa

The cocoa plant is cauliflorous, that is, the flowers and fruits are borne on the trunk and main branches. If unpollinated, cocoa flowers generally absciss within 24 hours after anthesis (Urquehart, 1961; Wood, 1975). On a full grown cocoa plant, thousands of flowers may develop in a year, but usually the proportion of successful pollination may only be about five percent (Urquehart, 1961). Other than incompatibility, which is often the case in many varieties of cocoa, flower wastage is often due to prolonged dry seasons, or heavy rains, that cause most of the flowers to dry up or abort (Darjanto and Satifah, 1984). Young (1986) suggested that another reason for pollination failure in cocoa flowers is the low population of pollinators during peak flowering seasons.

Cocoa is an Angiosperm. Seeds develop from fertilized ovules after the process of pollination and double fertilization. During these processes, one male gamete unites with the egg cell to form the zygote, and another unites with the two polar nuclei, or the secondary nucleus, to form the

primary endosperm nucleus (triple fusion). This marks the beginning of the process of seed formation (Dodd, 1968; Greulach, 1973; Fahn, 1982; Bewley and Black, 1978).

The time lag between pollination and fertilization for the majority of plants is between 10 to 25 hours, although in exceptional cases the interval may be several days (Kapil and Bhatnagar, 1975). In cocoa, fertilization occurs a few hours after pollination (Cheeseman, 1927).

Upon entry of the pollen tube into the embryo sac, the synergids are degenerated, as in sorghum. In maize, the synergid receiving the pollen tube degenerates, and the other remains healthy (Kapil and Bhatnagar, 1975). In cocoa, degeneration of one or both synergids is associated with the entry of pollen tube (Kapil and Bhatnagar, 1975).

Fruit Development

Following fertilization, the ovule develops into a seed, while the ovary into a fruit. These two processes usually occur more or less concurrently. However, fruit growth usually ceases before seed growth, sometimes long before, as in the case of pea (Milthorpe and Mooreby, 1974).

In cocoa, the young developing fruit is called "cherelle". During the first two to three months of its

development, it is often subjected to physiological wilting, commonly referred to as "cherelle wilt". This appears as a drying up and mummifying of the young fruits. The fruits are not shed, but wither while attached to the parent plant until they are knocked or blown off (Nichols, 1964; Wood, 1975; Uthaiah and Sulladmath, 1985). Cherelle wilt may account for a loss of up to 60 to 95 percent of the developing fruits (Wood, 1975; Darjanto and Satifah, 1984).

Previous studies had shown that cherelle wilt is a physiological thinning mechanism, resulting from competition for water and nutrients among the young fruits (pods), the older developing crop and the vegetative growth (Wood, 1975). Uthaiah and Sulladmath (1985), suggested that wilting could possibly be caused by the inability of the cherelles to mobilize metabolites. Earlier, Nichols (1965b) deduced from fruit thinning experiments that both biotic and physiological factors could contribute to cherelle wilt. The physiological component is a shortage of a growth factor produced in the vegetative organs which is necessary for fruit growth. There was no evidence that fungal infection caused the wilting syndrome, but biotic factors could produce the same effect. Further, Nichols (1965b) observed that during the development of cocoa pods, there are two peaks at which this wilt is most likely to occur, one at 50 days and the other at 70 days after fertilization.